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# Channel coordination through subsidy contract design in the mobile phone industry

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**Abstracts:** This paper examines the feasibility of employing subsidy contracts as a control mechanism to optimise the mobile phone sales channel. We investigate a dual-channel that consists of a telecommunication service operator (TSO) and a mobile phone manufacturer (MPM). The MPM's optimal production quantity and optimal retail price and the TSO's optimal service capacity and optimal service price are derived in both the decentralised and centralised MPSC models. The modelling results show that the coordinated MPSC leads to profit increase for the MPSC as a whole. More importantly, our analysis demonstrates that a properly designed subsidy contract can achieve the channel coordination in the MPSC. However, such channel coordination through subsidy contract is subject to certain conditions in which Pareto improvement can be achieved.

**Keywords:** Pricing policy, channel coordination, game theory, mobile phone supply chain, subsidy contract

# 1 Introduction

Over the past two decades, the mobile telecommunication sector has witnessed a rapid growth in both developed and developing economies. The increase in the number of mobile phone users has led to the significant growth of mobile service. According to recent forecast, global mobile service revenue will reach the height of 1,137 billion U.S. dollars in 2015 (Informa Telecoms & Media, 2013). However, the increase of global mobile service revenue does not guarantee that each member within the mobile phone supply chain (MPSC) will gain more profit. In fact, intense competitiveness has already escalated the complexity of the strategic interactions among members within the MPSC. We have already seen many high profile winners and, of course, casualties in the mobile telecommunication sector. To meet the challenges, members in the MPSC can no longer compete as independent members. Instead, they must coordinate with each other and work towards a unified system to improve their supply chain performance.

It is well known from the existing literature that channel coordination can improve the overall supply chain performance (Boyaci and Gallego 2004; Kanda and Deshmukh 2008). However, the main assumption ignores the competitive environment in which supply chain members operate. More importantly, MPSC is different from either traditional manufacturing supply chains or pure service supply chains. As a result, traditional supply chain theories may not be applicable. It is characterised in the following four aspects. (1) The main participating entities in the MPSC are telecommunication service operators (TSO), who provide the mobile telecommunication service, and mobile phone manufacturers (MPM), who produce mobile phones and product service. (2) In addition to the price and quality of mobile phones, both price and quality of telecommunication service complement each other and are essential to meet end customers' needs. (3) There exists a dual-channel in the MPSC, in which consumers can buy their mobile phones and telecommunication services from either the MPM or the TSO directly. For example, consumers can buy iPhones and service packages from Apple stores or from different TSOs. (4) The MPM and the TSO can either compete with each other for market share or alternatively coordinate with each other in setting up the prices and then negotiate with each other in distributing profit through subsidy contract (Chen and Wang

2015).

Given the inherent differences between the MPSC and the conventional manufacturing or service supply chains, we develop a model that links product and service prices to market demand and subsidy policies in a competitive market environment. More specifically, we consider the channel coordination problem in a MPSC that consists of an MPM and a TSO. The MPM can sell mobile phones to customers and the TSO can sell telecommunication service to customers respectively in a conventional supply chain or alternatively they can sell product and service bundled package to customers in a coordinated MPSC. Several questions are addressed in this article. They are listed as follows:

(1) What are the MPM's optimal production quantity and retail pricing policies and the TSO's optimal service capacity and pricing policies in a decentralised or centralised MPSC respectively?

(2) How to achieve supply chain coordination through subsidy contract and what is the effect of subsidy contract on MPSC decisions and its performance?

(3) How to design a subsidy contract? For instance, what is the optimal subsidy and who are the provider and the receiver of the subsidy?

(4) Under what conditions channel coordination through subsidy contract can achieve a win-win situation that MPSC members obtain a profit margin higher than they would do without contract?

Although there is a considerable amount of research in the literature on different aspects of channel coordination, very few studies have focused on coordination in the service supply chain (Tsay and Agrawal 2000, Boyaci and Gallego 2004, Chan and Chan 2010, Liu et al. 2013, Chen et al. 2015). Even fewer studies have made use of the mobile telecommunication sector as a case, which has distinctive supply chain characteristics as discussed earlier. It is important that the production economics research stream addresses the research gap through specifically designed modelling efforts. This paper aims at fulfilling this objective by modelling the channel coordination in the MPSC using the game theoretical approach. Generally speaking, in the game theory models, players make decisions to maximise their own utility, while taking into account that others are doing the same and that decisions made by players affect each other's performance (Nagarajan and Sošić 2008). The main

contributions of our work are summarised as follows:

(1) We develop MPSC models with an MPM and a TSO in both decentralised and centralised supply chain structures, in which, both the MPM and the TSO directly deal with the end customers and their demand is influenced by the pricing policies of both the mobile phone product and telecommunication service. Our paper extends the traditional supply chain that consists of sequential upstream manufacturer and downstream retailer that mainly considers product or service only.

(2) Through examining the feasibility of using subsidy contract as a control mechanism to coordinate the MPSC, our research extends the exiting literature by demonstrating how such an approach can be employed practically to obtain a win-win outcome for the MPSC members.

(3) Through studying the channel coordination in the MPSC, we analyse the effect of channel coordination, pricing policies, and subsidy contract on the MPSC performance. The analysis results will support firms in the mobile telecommunication industry to adopt the proper strategies in order to improve their competitiveness.

To the best of our knowledge, this paper represents the first attempt to study the channel coordination problem of the MPSC, in which, both the MPM and the TSO use price and subsidy to compete and cooperate with each other to maximise their own profits. The remainder of this article is organised as follows. After a brief review of relevant literature in Section 2, modelling formulations and assumptions are provided in Section 3. In Section 4 and 5 the optimal production quantity, optimal service capacity and pricing policies in a decentralised MPSC model and in a centralised MPSC model are presented respectively. In Section 6, we focus on how to achieve channel coordination through subsidy contract for the MPSC. In Section 7, some critical issues of channel coordination through subsidy contract are discussed. Finally, we discuss the managerial implications of our study and future work in Section 8.

## **2 Literature review**

Channel coordination is an important issue in marketing and supply chain management.

Relevant studies on the coordination problem have been well reported in the literature. Other terms e.g. integration, collaboration, and cooperation are also used in the studies on channel coordination problems. These terms are complementary to each other and when used in the supply chain context can easily be considered as a part of supply chain channel coordination (Kanda and Deshmukh 2008). To highlight our contributions, only the literature that is representative and particularly relevant to our study is reviewed.

The mobile phone industry has witnessed significant growth over the past two decades. Despite the importance to the economy and its unique features, studies on the MPSC are still rare in the operations and supply chain management literature. Among them, Catalan and Kotzab (2003) analysed the performance efficiency in the Danish MPSC and found its responsiveness was low. Their research emphasised the importance of the responsiveness and also suggested that collaboration between supply chain parties was crucial to improve the supply chain responsiveness. Eng (2006) provided some insights into the qualitative nature of mobile supply chain management but the research did not discuss the problems of the mobile phone industry. In addition, Eng (2006) mainly focused on the implications of mobile technology for supply chain management. Dedrick *et al.* (2011) analysed the distribution of value in the MPSC based on product-level data, and found that carriers and handset makers captured the most profit from each handset. Among the studies using quantitative approaches, Jiang *et al.* (2010) proposed an agent-based simulation approach to study the competitive and collaborative mechanisms for mobile service chains. Cricell *et al.* (2011) examined the competition among mobile network operators in the telecommunication supply chain focusing on different value chain components, the resulting competitive advantages and the appropriate value strategies. More recently, Chen and Wang (2015) investigated the free and bundled channels in the MPSC. Their research mainly focused on assessing the impact of supply chain power dynamics on the channel selection problem. Different to above mentioned studies, this research aims to derive optimal operations solutions for the MPSC members in both decentralised and centralised scenarios, and seeks a feasible mechanism to achieve the MPSC coordination which leads to our next wave of enquiry.

Effective management of supply chains requires coordination among various channel members. According to Jeuland and Shugan (1983), channel coordination was defined as the

setting of all manufacturer and retailer-related decisions at the levels that would maximise total channel profits. The literature on supply chain coordination is rich including the studies on coordinating manufacturing supply chains (Jeuland and Shugan 1983; Ingene and Parry 1995; Weng 1995; Iyer 1998; Tsay Agrawal 2004; Raju and Zhang 2005; Cai 2010) and the supply chain scenarios where service is considered (Ernst and Cohen 1992; Tsay and Arrawal 2000; Boyaci and Gallego 2004; Li et al. 2011; Chen and Shen 2012; and Liu et al. 2013). Different coordination mechanisms including quantity discount (Jeuland and Shugan 1983; Weng 1995; Raju and Zhang 2005), two-part tariff pricing policies (Ingene and Parry 1995; Raju and Zhang 2005; Swami and Shah 2013), pricing discount (Li et al. 2011), revenue sharing (Giannoccaro and Pontrandolfo 2004; Cachon and Lariviere 2005; Xiao et al. 2011; Zhou and Wang 2012), and option contracts (Zhao et al. 2010; Chen and Shen 2012) have been discussed as alternative mechanisms to coordinate different supply chain scenarios. Nevertheless, none of the above research has studied the coordination in the context of the MPSC, which is different from conventional manufacturing or service supply chain as we discussed earlier.

One key question is how to design a subsidy contract which can coordinate the MPSC and improve its performance, which is closely related to another stream of research that centres on supply chain coordination with contracts and contract negotiation. To develop a better understanding of the coordination issues, Kanda and Deshmukh (2008) conducted a systematic review which reports and reviews various perspectives on supply chain coordination. Their study also tried to understand and appreciate various mechanisms e.g. supply chain contracts, joint decision making, information technology, and information sharing that were available for coordination. Pasternack (1985) showed that buy-back contracts can achieve supply chain coordination. Taylor (2002) studied the supply chain coordination under sales-rebate contracts with sales effort effects. His research findings showed that a properly designed target rebate and returns contract achieves supply chain coordination and a win-win outcome when demand was influenced by retailer's sales effort. Giannoccaro and Pontrandolfo (2004) proposed a supply chain revenue sharing contract model for a three-stage supply chain, and demonstrated that the mechanism could achieve the system efficiency and improve the profits of all the supply chain parties. Cachon and Lariviere (2005)

also investigated revenue-sharing contracts in a two-echelon supply chain model with revenues determined by each retailer's purchase price and quantity, and demonstrated that revenue sharing could coordinate a supply chain with a price-setting newsvendor. Xiao et al. (2011) investigated coordination of a two-echelon supply chain via a revenue-sharing contract, in which a product quality assurance policy was provided and customer demand was sensitive to product quality, service quality and retail price. Zhou and Wang (2012) considered a supply chain coordination issue for newsvendor-type products with two ordering opportunities in a two-echelon supply chain. They proposed an improved revenue-sharing contract that could achieve perfect supply chain coordination. Ma et al. (2013) examined supply chain coordination issues between a retailer and a manufacturer where the market demand dependent on the retail price, the retailer's marketing effort, and the manufacturer's quality effort. Based on two-part tariff contract and cost sharing contract, they developed an effective contract to coordinate supply chain. Swami and Shah (2013) investigated the channel coordination in green supply chain management. In addition to the finding that profits were higher in the coordinated channel as compared to the case of the decentralised channel, their study also showed that a two-part tariff contract produced channel coordination in this problem. Nevertheless, among the existing literature on channel coordination with contracts, very few studies have considered subsidy contract as an effective control mechanism for supply chain coordination although it is a very common practice in the telecommunication sector.

Furthermore, although supply chain coordination often leads to improved supply chain performance collectively as demonstrated in previous research, it is not necessary that supply chain parties are willing to be coordinated if individual companies will be worse off through the coordination. For instance, Boyaci and Gallego (2004) used game-theoretical concepts to model customer service competition considering a market with two competing supply chains. Through the comparison of three competition scenarios, their research found that although coordination was a dominant strategy for the two competing supply chains, both of them were often worse off under the coordinated scenario relative to the uncoordinated scenario while the consumers are the only guaranteed beneficiary of coordination. Iyer (1998) studied how manufacturers should coordinate distribution channels when retailers compete in price and other important non-price factors. The research finding showed that a channel in which one



manufacturer chose to be coordinated while the other chose to be non-coordinated can be equilibrium in markets with weak brand loyalty. Cai (2010) investigated the influence of four supply chain structures with and without coordination on the supplier and the retailer. Their finding suggested that the channel selection and coordination preferences depend on parameters like channel base demand, channel, operational cost, and channel substitutability. Supply chain members would only take part in the coordination if Pareto improvement could be achieved (Zhao et al. 2010; Li et al. 2011). Therefore it is important to understand the conditions under which a win-win situation can be achieved through subsidy contract in the context of the MPSC.

This paper focuses on the coordination issues of the MPSC. Compared with the literature on supply chain coordination models, the critical difference of this paper does not only lie in the developed coordination model for the MPSC but also the analytical exploration of the issues concerning implementation of pricing policies and subsidy contracts in the MPSC, taking into account the unique characteristic of the MPSC. Different from most of two-echelon sequential supply chains, members in the MPSC deal with the end customers directly, and therefore customer demand is influenced by the prices of both the mobile phone and the telecom service. Different to the retail operation for complementary products/services where the price and quantity decisions of product and service are made by retailers, the same decisions on product and service are made by the manufacturer and the service provider respectively. Furthermore, the sequences of these decisions are different in the MPSC. These unique characteristics of this industry require particular modelling changes and these changes will lead to some new results.

### 3 Model Formulation and Assumptions

We consider a MPSC that consists of a telecom service operator (TSO) and a mobile phone manufacturer (MPM). For each mobile phone, the MPM's unit retail price is  $p_m$ , and its unit manufacturing cost is  $c_m$ . The TSO's revenue from one customer over the service period is  $p_o$ , and its unit service cost over the service period is  $c_o$ .

Without considering subsidy contract, mobile phone sale is the only source of revenue

for the MPM, and service revenue is the only source for the TSO. Considering subsidy, in addition to the mobile phone sales revenue, the MPM can get a second revenue source through the subsidy  $\theta$  ( $0 < \theta < p_o$ ) from the TSO or alternatively incur a cost through giving subsidy  $\theta$  ( $-p_m < \theta < 0$ ) to the TSO. At the same time, in addition to the service revenue, the TSO can get a second revenue source through the subsidy  $\theta$  ( $-p_m < \theta < 0$ ) from the MPM or alternatively incur a cost through giving subsidy  $\theta$  ( $0 < \theta < p_o$ ) to the MPM.

Similar to the conventional demand function, demand is defined by the equation  $p_i = \alpha_i - \beta q_i - \gamma q_j$ ,  $i, j = m, o$ ,  $i \neq j$ , where  $\alpha_i$  denotes the maximum unit retail price of mobile phone/telecom service  $i$ ,  $\beta$  is the demand sensitivity,  $\gamma$  is the cross-demand sensitivity. The demand is assumed to be deterministic, so the demand equals to the quantity sold by the firm. In addition, the demand  $i$  is influenced by the firm  $i$ 's retail price and firm  $j$ 's retail price. Then in the inverse demand function, the price  $i$  is dependent on the quantity sold by firm  $i$  and the quantity sold by firm  $j$ . Through the inversion of price and quantity, the objective functions for both parties are concave and hence the optimal decisions can be found with basic algebra. We assume  $\beta > \gamma > 0$ , which appears reasonable because mobile phone price is relatively more sensitive to mobile phone demand than telecom service demand. Although the assumption of a simple demand function has its limitations, this linear inverse demand function has been often used in operations management (de Mesnard, 2009 and 2011; Shin and Tunca, 2010; Chen et al. 2012; Shang et al. 2015) as well as marketing research (Ingene et al., 1995; Padmanabhan et al., 1997).

The relationship between mobile phone and telecom operator service is complementary, then we assume that eventual sales quantities of mobile phones and telecom service contracts are the same although each party will get different optimal quantities ( $q^m, q^o$ ) according to the demand function. We also define  $\Delta_m = \alpha_m - c_m$ , which means *maximum possible unit profit of mobile phone*; and define  $\Delta_o = \alpha_o - c_o$ , which means *maximum possible unit profit of telecom service*.

## 4 Decentralised MPSC

In a decentralised MPSC, non-cooperative game theory is applied, in which the manufacturer and the operator are rational and self-interested. More specifically, each aims to maximise its own profit. In addition, a Nash game is used to model the MPSC as it is assumed to have a balanced power structure between the manufacturer and the operator. In the Nash game, both players make the decision simultaneously, where the MPM decides its mobile phone retail price and the TSO decides its service price according to the customer demand. After the customer demand is realised, the MPM gains its mobile phone sales revenue and the TSO gains its service revenue.

The MPM's profit in a decentralised MPSC, denoted  $\pi_m^f(q)$ , is

$$\pi_m^f(q) = p_m q - c_m q \quad (1)$$

The first term is total sales revenue and the second term is total manufacturing cost. Then

$$\pi_m^f(q) = [\Delta_m - (\beta + \gamma)q]q \quad (2)$$

The TSO's profit in a decentralised MPSC, denoted  $\pi_o^f(q)$ , is

$$\pi_o^f(q) = p_o q - c_o q \quad (3)$$

The first term is total service revenue and the second term is total service cost. Then

$$\pi_o^f(q) = [\Delta_o - (\beta + \gamma)q]q \quad (4)$$

As to the MPM's optimal production quantity ( $q^m$ ) and optimal retail price ( $p^m$ ), and TSO's optimal service capacity ( $q^o$ ) and optimal service price ( $p^o$ ) in a decentralised MPSC, the following proposition is obtained:

**Proposition 1** *In a decentralised MPSC model,  $q^m = \frac{\Delta_m}{2(\beta+\gamma)}$ ,  $q^o = \frac{\Delta_o}{2(\beta+\gamma)}$ ,  $p^m = \frac{\alpha_m + c_m}{2}$  and  $p^o = \frac{\alpha_o + c_o}{2}$ .*

This proposition means that in a decentralised MPSC, the MPM's optimal production quantity and the TSO's optimal service capacity exist, which are decided by their maximum possible unit profits, the demand sensitivity, and the cross-demand sensitivity. That is, both the MPM's optimal production quantity and TSO's optimal service capacity increase in their maximum possible unit profits, and decrease in the demand sensitivity and the cross-demand

sensitivity. In a decentralised MPSC, the MPM's optimal retail price and TSO's optimal service price exist. Both the MPM's optimal retail price and TSO's optimal service price increase in their maximum unit retail price and unit manufacturer/service cost.

The relationship between mobile phone and telecom service is complementary. Therefore the actual sale quantity for both mobile phone and telecom service, denoted  $q^f$ , is  $q^f = \min(q^m, q^o)$ . Then MPM's profit in a decentralised MPSC is

$$\pi_m^f(q^f) = [\Delta_m - (\beta + \gamma)q^f]q^f \quad (5)$$

The TSO's profit in a decentralised MPSC is

$$\pi_o^f(q^f) = [\Delta_o - (\beta + \gamma)q^f]q^f \quad (6)$$

## 5 Centralised MPSC

In a centralised MPSC, the MPM and the TSO jointly make the decision to optimise the overall profit of the MPSC. The decision problem faced by central controller is to decide the mobile phone retail price and the telecom service price according to the customer demand,  $q$ . The profit for the centralised MPSC, denoted  $\pi^l(q)$ , is

$$\pi^l(q) = (p_m - c_m)q + (p_o - c_o)q \quad (7)$$

The first part is the profit of mobile phone and the second term is the profit of telecom service. Then

$$\pi^l(q) = [\Delta_m - (\beta + \gamma)q^f]q + [\Delta_o - (\beta + \gamma)q^f]q \quad (8)$$

As the central controller's optimal production/service capacity ( $q^l$ ), optimal retail price ( $p_m^l$ ) and optimal service price ( $p_o^l$ ), the following proposition is obtained.

**Proposition 2** *In a centralised MPSC,  $q^l = \frac{\Delta_m + \Delta_o}{4(\beta + \gamma)}$ ,  $p_m^l = \frac{3\alpha_m + c_m - \Delta_o}{4}$  and  $p_o^l = \frac{3\alpha_o + c_o - \Delta_m}{4}$ .*

This proposition means that in a centralised MPSC, the central controller's optimal production/service capacity exists, which is decided by their maximum possible unit profits, the demand sensitivity and the cross-demand sensitivity. That is, the central controller's optimal production/service capacity increases in both the *maximum possible unit profit of mobile phone* and the *maximum possible unit profit of telecom service*, and decreases in both

the demand sensitivity and the cross-demand sensitivity. It is interesting to see that  $q^I$  is the mean of  $q^m$  and  $q^o$ . This can be explained by the fact that both the maximum possible unit profits ( $\Delta_m$  and  $\Delta_o$ ) of the MPM and the TSO affect the central controller's optimal production/service capacity and their effect on  $q^I$  is equally distributed in a supply chain where the MPM and the TSO are assumed to have a balanced power relationship. Moreover, in a centralised MPSC, the central controller's optimal mobile phone retail price and optimal service price exist. That is, the central controller's optimal mobile phone retail price increases in both her maximum unit retail price and her unit manufacturer cost, and decreases in the *maximum possible unit profit of telecom service*; the central controller's optimal service price increases in both her maximum unit retail price and her unit service cost, and decreases in the *maximum possible unit profit of mobile phone*. Then, the centralised MPSC's profit is

$$\pi^I(q^I) = \frac{(\Delta_m + \Delta_o)^2}{8(\beta + \gamma)} \quad (9)$$

From proposition 1 and proposition 2, we can directly obtain that the decentralised MPSC cannot be coordinated. To achieve channel coordination, we will introduce subsidy contract to the MPSC in the next section.

## 6 MPSC with Subsidy Contract

Similar to the decentralised model, a non-cooperative Nash game is applied to model the MPSC considering subsidy contract. The sequence of events is as follows. Firstly, the TSO negotiates the subsidy with the MPM. Then the MPM decides its mobile phone retail price and the TSO decides its service price simultaneously according to the customer demand and the subsidy. Finally, when the customer demand is realised, the MPM and the TSO gain their revenues respectively. Considering subsidy contract, if the TSO gives subsidy to the MPM, then the MPM has two revenue sources: mobile phone sales revenue and subsidy from the TSO. The TSO has additional cost which is the subsidy to the MPM. On the other hand, if the MPM gives subsidy to the TSO, then the TSO has two revenue sources: service sales revenue and subsidy from the MPM. The MPM has additional cost, which is the subsidy to the TSO. The relationship between the mobile phone and telecom service is complementary and bundled.

In a MPSC with subsidy contract, the MPM's profit, denoted  $\pi_m^b(q)$ , is

$$\pi_m^b(q) = p_m q - c_m q + \theta q \quad (10)$$

The first term is the total sale revenue of mobile phone. The second term is the total manufacturing cost. And the last term represents the subsidy from/to the TSO. Then

$$\pi_m^b(q) = [\Delta_m - (\beta + \gamma)q + \theta]q \quad (11)$$

The TSO's profit in a MPSC with subsidy contract, denoted  $\pi_o^b(q)$ , is

$$\pi_o^b(q) = p_o q - c_o q - \theta q \quad (12)$$

The first term is the service revenue of telecom service. The second term is the total service cost. And the last term represents the subsidy to/from the MPM. Then

$$\pi_o^b(q) = [\Delta_o - (\beta + \gamma)q - \theta]q \quad (13)$$

As to the MPM's optimal production quantity ( $q^b$ ) and optimal retail price ( $p_m^b$ ), the TSO's optimal service capacity ( $q^b$ ) and optimal service price ( $p_o^b$ ), and the optimal subsidy ( $\theta^b$ ) in a MPSC with subsidy contract, the following proposition is obtained:

**Proposition 3** *In a MPSC model with subsidy contract,  $q^b = \frac{\Delta_m + \Delta_o}{4(\beta + \gamma)}$ ,  $p_m^b = \frac{3\alpha_m + c_m - \Delta_o}{4}$ ,  $p_o^b = \frac{3\alpha_o + c_o - \Delta_m}{4}$  and  $\theta^b = \frac{\Delta_o - \Delta_m}{2}$ .*

The proposition means that in a MPSC with subsidy contract, the MPM's optimal production quantity and TSO's optimal service capacity exist. Both the MPM's optimal production quantity and TSO's optimal service capacity increase in both the *maximum possible unit profit of mobile phone* and the *maximum possible unit profit of telecom service*, and decrease in both the demand sensitivity and cross-demand sensitivity. The MPM's optimal sale price and the TSO's optimal service price exist. The MPM's optimal sale price increases in both her maximum unit retail price and her unit manufacturer cost, and decreases in the *maximum possible unit profit of telecom service*; the TSO's optimal service price increases in both her maximum unit retail price and her unit service cost, and decreases in the *maximum possible unit profit of mobile phone*. The optimal subsidy also exists and is decided by the relationship between the *maximum possible unit profit of mobile phone* and the *maximum possible unit profit of telecom service*. If the *maximum possible unit profit of telecom service* is higher than the *maximum possible unit profit of mobile phone*, then the TSO should give subsidy to the MPM. On the other hand, if the *maximum possible unit profit of*

telecom service is lower than the maximum possible unit profit of mobile phone, then the MPM should give subsidy to the TSO.

The MPM's profit in a MPSC with subsidy contract is

$$\pi_m^b(q^b) = \frac{(\Delta_m + \Delta_o)^2}{16(\beta + \gamma)} \quad (14)$$

The TSO's profit in a MPSC with subsidy contract is

$$\pi_o^b(q^b) = \frac{(\Delta_m + \Delta_o)^2}{16(\beta + \gamma)} \quad (15)$$

From proposition 2 and proposition 3, we can directly gain the following proposition:

**Proposition 4** *In a MPSC with subsidy contract, the MPSC can be coordinated with the optimal subsidy  $\theta^b = \frac{\Delta_o - \Delta_m}{2}$ .*

This proposition means that in a MPSC with subsidy contract, the MPSC can be coordinated with certain condition.

## 7 Discussions

In this section, we will discuss the effect of subsidy on the MPSC's decisions and profits. As to the effect of subsidy on the MPSC's optimal quantity, the following proposition is obtained.

**Proposition 5** *If  $\Delta_m \geq \Delta_o$ , then  $q^b \leq q^m$ ,  $p_m^b \geq p^m$ ,  $q^b \geq q^o$  and  $p_o^b \leq p^o$ ; if  $\Delta_m < \Delta_o$ , then  $q^b > q^m$ ,  $p_m^b < p^m$ ,  $q^b < q^o$ , and  $p_o^b > p^o$ .*

The proposition means that if the maximum possible unit profit of mobile phone is higher than the maximum possible unit profit of telecom service, then the MPM's optimal production quantity in a MPSC with subsidy contract is less than that without subsidy contract and the TSO's optimal telecom service capacity with subsidy contract is more than that without subsidy contract. The MPM's optimal retail price in a MPSC with subsidy contract is higher than that without subsidy contract and the TSO's optimal telecom service price with subsidy contract is lower than that without subsidy contract. If the maximum possible unit profit of mobile phone is higher than the maximum possible unit profit of telecom service, then the MPM's optimal production quantity in a MPSC with subsidy contract is more than that without subsidy contract and the TSO's optimal telecom service capacity with subsidy contract is less than that without subsidy contract. The MPM's optimal retail price in a MPSC

with subsidy contract is lower than that without subsidy contract and the TSO's optimal telecom service price with subsidy contract is higher than that without subsidy contract.

As to the effect of subsidy on the MPSC's profit, the following proposition is obtained.

**Proposition 6** *If  $\Delta_m - \Delta_o > 4\Delta_o$  or  $\Delta_o - \Delta_m > 4\Delta_m$ , then  $\pi_m^b(q^b) > \pi_m^f(q^f)$  and  $\pi_o^b(q^b) > \pi_o^f(q^f)$ ; if  $0 < \Delta_m - \Delta_o \leq 4\Delta_o$ , then  $\pi_m^b(q^b) \leq \pi_m^f(q^f)$  and  $\pi_o^b(q^b) \geq \pi_o^f(q^f)$ ; if  $0 \leq \Delta_o - \Delta_m \leq 4\Delta_m$ , then  $\pi_o^b(q^b) \leq \pi_o^f(q^f)$  and  $\pi_m^b(q^b) \geq \pi_m^f(q^f)$ .*

From this proposition, we know that if the gap between the *maximum possible unit profit of mobile phone* and the *maximum possible unit profit of telecom service* is four times higher than the *maximum possible unit profit of mobile phone* or the *maximum possible unit profit of telecom service*, then both the MPM and the TSO will gain more profit in a MPSC with subsidy contract than that without subsidy contract. That is, the MPSC will achieve Pareto improvement with subsidy contract. In this scenario, both the MPM and the TSO are willing to accept subsidy contract and the MPSC can be coordinated. On the other hand, if the gap between the *maximum possible unit profit of mobile phone* and the *maximum possible unit profit of telecom service* is lower than or equal to four times of the *maximum possible unit profit of mobile phone* or the *maximum possible unit profit of telecom service*, then the MPM or the TSO will gain less profit in a MPSC with subsidy contract than that without subsidy contract. That is, the MPSC will not obtain a win-win situation with subsidy contract. In this scenario, the MPM or the TSO are unwilling to accept subsidy contract and the MPSC cannot be coordinated.

The mobile phone industry is one of the fastest growing sectors yet to receive much academic attention. It is also a competitive marketplace, in which we witnessed some dramatic rises and falls of high profile companies. In addition to technological advancement and innovations, mobile phone manufacturers and telecom service operators have opportunities to improve their profitability by employing right pricing strategies via coordinating the MPSC. Our research findings provide important managerial and practical implications to firms in the mobile phone industry. More specifically, our findings enable the MPM and the TSO to derive the optimal decisions on the production quantity, service capacity, and prices, in both the decentralised and centralised MPSC. Secondly, our findings



do not only demonstrate subsidy contract as an effective mechanism for achieving the MPSC coordination, but also provide firms in the MPSC a useful guideline to design a practical subsidy contract that brings benefits to both the MPM and the TSO collectively as well as individually. In addition, our research identifies the conditions, under which, the Pareto improvement can be achieved for the MPSC. Many firms are simply unaware that the MPSC cannot be coordinated under certain conditions since the MPSC members' economic performance may be worse off individually although the overall profit increases for the whole MPSC. Our findings will support firms in this competitive industry to adopt the right strategies and make appropriate operational decisions to improve their competitiveness.

## **8 Conclusions and Suggestions for Further Research**

In this article, we propose a model of the MPSC that represents the interaction between final consumers, a MPM and a TSO, taking into account the distinctive features of the MPSC in which both the manufacturer and the service provider can use prices and subsidy contract to compete and cooperate with each other. We address the issue of supply chain channel management between a MPM and a TSO where the market demand is influenced by the MPM's product price and the TSO's service price. We derive the MPM's optimal production quantity and optimal retail price and the TSO's optimal service capacity and optimal service price in both decentralised and centralised MPSCs. We explore analytically the issues concerning implementation of the subsidy contract as channel coordination mechanism. Our analysis results show that the MPSC can be coordinated through subsidy contract and it increases the profit of the MPSC as a whole. However, such channel coordination is subject to the difference between the maximum possible unit profit of mobile phone and the maximum possible unit profit of telecom service. Only when the profit difference between the two increases to a certain level, the MPSC can be coordinated and achieve Pareto improvement through subsidy contract.

The mobile telecommunication sector has unique supply chain features that are different from traditional manufacturing supply chains or service supply chains. It is mainly reflected in three aspects: (i) the nature of demand, (ii) the decision maker, and (iii) the sequence of

decisions. First, different to most of two-echelon sequential supply chains, both the MPM and the TSO directly deal with the end customers. Therefore, customer demand is influenced by the prices of both the mobile phone product and telecom service. Second, different to the traditional retailing operation for complementary products/services where the price and quantity decisions of product and service are made by retailer, the MPM makes the decision for the price and quantity of the mobile product and the TSO makes the decision for the price and quantity of the service contract respectively. Third, different to other two-echelon supply chains e.g. retailing or manufacturing where the price/quantity decisions are often made in sequence by supply chain members, the decisions are simultaneously made by the MPM and the TSO in the decentralised MPSC or the decentralised MPSC with subsidy contract.

It is also the industry sector that subsidy contract is extensively implemented to increase the sales of mobile phones and telecom services. In a MPSC, a subsidy contract can be a two-way payment between the MPSC members. For instance, in addition to the retail sales price of a mobile phone product, a TSO pays MPM a percentage of the revenue generated from its mobile telecom service as subsidy, or in an opposite way, a MPM pays TSO a percentage of the revenue generated from its mobile phone sales as subsidy. Therefore, it is different to other popular control mechanisms used in the channel coordination e.g. channel rebate contract (Taylor 2002) or revenue sharing contract (Cachon and Lariviere 2005). Despite the uniqueness of its retail channel structure and the extensive use of subsidy contract in the mobile telecommunication industry, little academic literature has examined this important problem in a similar setting. To the best of our knowledge, this is the first study of the channel coordination and subsidy contract problem using the case of the MPSC. The analyses of this paper indicate the following insights.

Mobile phone manufacturers and telecom service operators have an opportunity to improve profitability further by better coordinated supply chain channel since the coordinated MPSC leads to profit increase for the supply chain as a whole. The optimal decisions on production quantity, service capacity, pricing, and subsidy are dependent on the maximum possible unit profit of mobile phone and telecom service, the demand sensitivity, and the cross-demand sensitivity. Our analysis also demonstrates that a properly designed subsidy contract can achieve the coordination of the MPSC. Interestingly, the channel coordination

through subsidy contract is only practical in the certain condition under that MPSC members obtain a level of profit no less than the profit they would gain without subsidy contract. This finding supports the view of Ingene and Parry (2000) that channel coordination should no longer be regarded as the ultimate goal, which supply chain managers should uncritically pursue because supply chain members are ultimately interested in their own profitability. Other factors beyond those we have considered may also influence the decision to offer subsidy contract between supply chain members. For instance, even for those conditions that an MPM or a TSO will obtain a profit margin lower than they would do without subsidy contract, some firms may still choose to sacrifice a short-term profit decrease and to be bundled with a dominant player through subsidy contract in order to build a strategic partnership with a dominant MPSC member and increase their market share for long-term growth. Furthermore, in case of complements (say, mobile telecom service and home broadband), the TSO may discount the mobile telecom service offered under subsidy contract to spur sales of the other service e.g. home broadband. We leave these issues to be considered for future research.

Similar to any other model published in the literature, the present model is also based on some assumptions. For example, our model assumes that the MPSC consisted of one MPM and one TSO with deterministic demand. This specific configuration of a supply chain enables researchers to model supply chain decisions and draw interesting insights from the analysis. One important extension of this work is to include stochastic demand and consider multiple MPMs and multiple TSOs in the model. Such an extension will be interesting and require a new set of models. Furthermore, the number of mobiles sold on the market and the number of contracts are assumed to be the same. In fact, many people keep their contracts over years but change the mobile every year. Although it is less common, some people keep their mobile phones over years but change or renew contract every year, which also lead to the difference in the numbers of mobile phones and service contacts. One future research direction is to incorporate the other two market scenarios in modelling the MPSC. Another research direction is to examine the impacts of product quality and service quality on the optimal pricing and channel coordination strategies. Moreover, this study can also be applied to other technology and service industries which share similar characteristics of the MPSC. It is a

more challenging research topic if these extensions are incorporated in the model, but could certainly provide more useful insights. We believe the ideas and models presented in this research lay the inspirational ground for future research in these avenues.

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## Appendix

### Proof of Proposition 1

From (2), we get  $\frac{d\pi_m^f(q)}{dq} = -(\beta + \gamma)q + \Delta_m - (\beta + \gamma)q = \Delta_m - 2(\beta + \gamma)q$  and  $\frac{d^2\pi_m^f(q)}{dq^2} = -2(\beta + \gamma) < 0$ , so  $\pi_m^f(q)$  is concave in  $q$ . Let  $\frac{d\pi_m^f(q)}{dq} = 0$ , we get  $\Delta_m - 2(\beta + \gamma)q = 0$ . Then  $q^m = \frac{\Delta_m}{2(\beta + \gamma)}$ . So,  $p^m = \alpha_m - (\beta + \gamma)q^m = \frac{\alpha_m + c_m}{2}$ , that is,  $p^m = \frac{\alpha_m + c_m}{2}$ .

Similarly, from (4), we get  $\frac{d\pi_o^f(q)}{dq} = -(\beta + \gamma)q + \Delta_o - (\beta + \gamma)q = \Delta_o - 2(\beta + \gamma)q$  and  $\frac{d^2\pi_o^f(q)}{dq^2} = -2(\beta + \gamma) < 0$ , so  $\pi_o^f(q)$  is concave in  $q$ . Let  $\frac{d\pi_o^f(q)}{dq} = 0$ , we get  $\Delta_o - 2(\beta + \gamma)q = 0$ . Then  $q^o = \frac{\Delta_o}{2(\beta + \gamma)}$ . So,  $p^o = \alpha_o - (\beta + \gamma)q^o = \frac{\alpha_o + c_o}{2}$ , that is,  $p^o = \frac{\alpha_o + c_o}{2}$ .

This completes the proof.

### Proof of Proposition 2

From (8), we get  $\frac{d\pi^l(q)}{dq} = -2(\beta + \gamma)q + \Delta_m + \Delta_o - 2(\beta + \gamma)q = \Delta_m + \Delta_o - 4(\beta + \gamma)q$ ,  $\frac{d^2\pi^l(q)}{dq^2} = -4(\beta + \gamma) < 0$ , so  $\pi^l(q)$  is concave in  $q$ . Let  $\frac{d\pi^l(q)}{dq} = 0$ , we get  $\Delta_m + \Delta_o - 4(\beta + \gamma)q = 0$ . That is,  $q^l = \frac{\Delta_m + \Delta_o}{4(\beta + \gamma)}$ . Then,  $p_m^l = \alpha_m - (\beta + \gamma)q^l = \frac{3\alpha_m + c_m - \Delta_o}{4}$  and  $p_o^l = \alpha_o - (\beta + \gamma)q^l = \frac{3\alpha_o + c_o - \Delta_m}{4}$ . This completes the proof.

### Proof of Proposition 3

From (11), we get  $\frac{d\pi_m^b(q)}{dq} = -(\beta + \gamma)q + \Delta_m - (\beta + \gamma)q + \theta = \Delta_m - 2(\beta + \gamma)q + \theta$  and  $\frac{d^2\pi_m^b(q)}{dq^2} = -2(\beta + \gamma) < 0$ . So,  $\pi_m^b(q)$  is concave in  $q$ . Let  $\frac{d\pi_m^b(q)}{dq} = 0$ , we get  $\Delta_m - 2(\beta + \gamma)q + \theta = 0$ . Then  $q^b = \frac{\Delta_m + \theta}{2(\beta + \gamma)}$ .

Similarly, from (13), we get  $\frac{d\pi_o^b(q)}{dq} = -(\beta + \gamma)q + \Delta_o - (\beta + \gamma)q - \theta = \Delta_o - 2(\beta + \gamma)q - \theta$  and  $\frac{d^2\pi_o^b(q)}{dq^2} = -2(\beta + \gamma) < 0$ , so  $\pi_o^b(q)$  is concave in  $q$ . Let  $\frac{d\pi_o^b(q)}{dq} = 0$ , we get  $\Delta_o - 2(\beta + \gamma)q - \theta = 0$ . Then  $q^b = \frac{\Delta_o - \theta}{2(\beta + \gamma)}$ .

Let  $\frac{\Delta_m + \theta}{2(\beta + \gamma)} = \frac{\Delta_o - \theta}{2(\beta + \gamma)}$ , we get  $\theta^b = \frac{\Delta_o - \Delta_m}{2}$ , then  $q^b = \frac{\Delta_m + \Delta_o}{4(\beta + \gamma)}$ . Then,  $p_m^b = \alpha_m - (\beta + \gamma)q^b = \frac{3\alpha_m + c_m - \Delta_o}{4}$  and  $p_o^b = \alpha_o - (\beta + \gamma)q^b = \frac{3\alpha_o + c_o - \Delta_m}{4}$ . This completes the proof.

### Proof of Proposition 5

From proposition 1 and proposition 3, we get  $q^b - q^m = \frac{\Delta_m + \Delta_o}{4(\beta + \gamma)} - \frac{\Delta_m}{2(\beta + \gamma)} = \frac{\Delta_o - \Delta_m}{4(\beta + \gamma)}$ ,  $p_m^b - p^m = \frac{3\alpha_m + c_m - \Delta_o}{4} - \frac{\alpha_m + c_m}{2} = \frac{\Delta_m - \Delta_o}{4}$ ,  $q^b - q^o = \frac{\Delta_m + \Delta_o}{4(\beta + \gamma)} - \frac{\Delta_o}{2(\beta + \gamma)} = \frac{\Delta_m - \Delta_o}{4(\beta + \gamma)}$ , and  $p_o^b - p^o = \frac{3\alpha_o + c_o - \Delta_m}{4} - \frac{\alpha_o + c_o}{2} = \frac{\Delta_o - \Delta_m}{4}$ . Then, if  $\Delta_m \geq \Delta_o$ , then  $q^b - q^m \leq 0$ ,  $p_m^b - p^m \geq 0$ ,  $q^b - q^o \geq 0$ , and  $p_o^b - p^o \leq 0$ . That is,  $q^b \leq q^m$ ,  $p_m^b \geq p^m$ ,  $q^b \geq q^o$  and  $p_o^b \leq p^o$ ; if  $\Delta_m < \Delta_o$ , then  $q^b - q^m > 0$ ,  $p_m^b - p^m < 0$ ,  $q^b - q^o < 0$  and  $p_o^b - p^o > 0$ . That is,  $q^b > q^m$ ,  $p_m^b < p^m$ ,  $q^b < q^o$ , and  $p_o^b > p^o$ . This completes the proof.



### Proof of Proposition 6

From proposition 1, we get  $q^m - q^o = \frac{\Delta_m}{2(\beta+\gamma)} - \frac{\Delta_o}{2(\beta+\gamma)} = \frac{\Delta_m - \Delta_o}{2(\beta+\gamma)}$ .

(i) If  $\Delta_m > \Delta_o$ , then  $q^m \geq q^o$ , that is,  $q^f = \min(q^m, q^o) = q^o$ . Then MPM's profit in a MPSC without subsidy contract is  $\pi_m^f(q^f) = \pi_m^f(q^o) = [\Delta_m - (\beta + \gamma)q^o]q^o = \frac{2\Delta_m\Delta_o - \Delta_o^2}{4(\beta+\gamma)}$ .

The TSO's profit in a MPSC without subsidy contract is  $\pi_o^f(q^f) = \pi_o^f(q^o) = [\Delta_o - (\beta + \gamma)q^o]q^o = \frac{(\Delta_o - \beta - \gamma)^2}{4(\beta+\gamma)}$ . Then, from (14), we get  $\pi_m^b(q^b) - \pi_m^f(q^f) = \frac{(\Delta_m + \Delta_o)^2}{16(\beta+\gamma)} - \frac{2\Delta_m\Delta_o - \Delta_o^2}{4(\beta+\gamma)} = \frac{(\Delta_m - \Delta_o)(\Delta_m - 5\Delta_o)}{16(\beta+\gamma)}$ . So, if  $\Delta_m - 5\Delta_o > 0$ , that is,  $\Delta_m - \Delta_o > 4\Delta_o$ , then  $\pi_m^b(q^b) > \pi_m^f(q^f)$ ; if  $0 < \Delta_m - \Delta_o \leq 4\Delta_o$ , then  $\pi_m^b(q^b) \leq \pi_m^f(q^f)$ . From (15), we get  $\pi_o^b(q^b) - \pi_o^f(q^f) = \frac{(\Delta_m + \Delta_o)^2}{16(\beta+\gamma)} - \frac{\Delta_o^2}{4(\beta+\gamma)} > \frac{\Delta_o^2}{4(\beta+\gamma)} - \frac{\Delta_o^2}{4(\beta+\gamma)} = 0$ , then  $\pi_o^b(q^b) > \pi_o^f(q^f)$ .

(ii) If  $\Delta_m \leq \Delta_o$ , then  $q_m^f \leq q_o^f$ , that is,  $q^f = \min(q^m, q^o) = q^m$ . Then MPM's profit in a MPSC without subsidy contract is  $\pi_m^f(q^f) = \pi_m^f(q^m) = [\Delta_m - (\beta + \gamma)q^m]q^m = \frac{\Delta_m^2}{4\beta}$ .

The TSO's profit in a MPSC without subsidy contract is  $\pi_o^f(q^f) = \pi_o^f(q^m) = [\Delta_o - (\beta + \gamma)q^m]q^m = \frac{2\Delta_o\Delta_m - \Delta_m^2}{4\beta}$ . Then, from (14) we get  $\pi_m^b(q^b) - \pi_m^f(q^f) = \frac{(\Delta_m + \Delta_o)^2}{16(\beta+\gamma)} - \frac{\Delta_m^2}{4(\beta+\gamma)} \geq \frac{\Delta_m^2}{4(\beta+\gamma)} - \frac{\Delta_m^2}{4(\beta+\gamma)} = 0$ . So,  $\pi_m^b(q^b) \geq \pi_m^f(q^f)$ . From (15), we get that  $\pi_o^b(q^b) - \pi_o^f(q^f) = \frac{(\Delta_m + \Delta_o)^2}{16(\beta+\gamma)} - \frac{2\Delta_o\Delta_m - \Delta_m^2}{4(\beta+\gamma)} = \frac{(\Delta_o - \Delta_m)(\Delta_o - 5\Delta_m)}{16(\beta+\gamma)}$ . So, if  $\Delta_o - 5\Delta_m > 0$ , that is,  $\Delta_o - \Delta_m > 4\Delta_m$ , then  $\pi_o^b(q^b) > \pi_o^f(q^f)$ ; if  $0 \leq \Delta_o - \Delta_m \leq 4\Delta_m$ , then  $\pi_o^b(q^b) \leq \pi_o^f(q^f)$ .

Hence, if  $\Delta_m - \Delta_o > 4\Delta_o$  or  $\Delta_o - \Delta_m > 4\Delta_m$ , then  $\pi_m^b(q^b) > \pi_m^f(q^f)$  and  $\pi_o^b(q^b) > \pi_o^f(q^f)$ ; if  $0 < \Delta_m - \Delta_o \leq 4\Delta_o$ , then  $\pi_m^b(q^b) \leq \pi_m^f(q^f)$  and  $\pi_o^b(q^b) \geq \pi_o^f(q^f)$ ; if  $0 \leq \Delta_o - \Delta_m \leq 4\Delta_m$ , then  $\pi_o^b(q^b) \leq \pi_o^f(q^f)$  and  $\pi_m^b(q^b) \geq \pi_m^f(q^f)$ . This completes the proof.